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Comparative study of biodiesel, GTL fuel and their blends in context of engine performance and exhaust emission

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Abstract

Crude oil price hikes, energy security concerns and environmental drivers have turned the focus on alternative fuels. Gas to liquid fuel (GTL) derived from Fisher-Tropsch synthesis, is regarded as a promising alternative diesel fuel, considering the adeptness to use directly as a diesel fuel or in blends with petroleum-derived diesel in CI engines. GTL has distinctly different characteristics than fossil diesel fuel due to its paraffinic nature, virtually zero sulphur, low aromatic contents and very high cetane number. In this study, an unmodified single cylinder 4 –stroke diesel engine was used to investigate diesel, GTL fuel and their blends in terms of engine performance and exhaust emission characteristics. GTL and its blends demonstrated improved engine performance increasing maximum power 9.1%, brake thermal efficiency 20% and lowering BSFC 9.1% than diesel. Exhaust emissions also showed diminutions in CO (22~25%), HC (30~40%) and NO (6~8%). These improvements ensure the potential for the application of GTL diesel blends.

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Keywords: GTL ; Biodiesel; Fuel-blends ;Engine Performance ; Exhaust Emission.

1. Introduction

The gradual advancement of civilization associated with the growth of transport sector has influenced the excessive usage of fossil fuels, initiating a confrontation of dual exigency between abrupt depletion of fossil fuel as well as

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environmental degradation. The projections up to 2020 demonstrate the increased demand of fossil fuels up to three times that will boost the pollution levels in terms of airborne pathogens (i.e. infections, particles and chemicals), greenhouse effect in context of local, territorial and global spectrum [1]. In these consequences, a strong worldwide drive towards alternative liquid fuels for transportation, mainly driven by emissions reduction, energy security concerns, volatility in the fuel price and the search for renewable fuels to compliment the dwindling world fuel supplies. Gas to Liquid fuels synthesized from natural gas by means of Fisher -Tropsch process can play a promising role as a clean alternative fuel [2]. GTL fuel has several distinguished beneficial properties like higher Cetane number, absence of PAH content, virtually zero sulphur, negligible amounts of aromatics and hetero atomic species like sulphur and nitrogen [2-5]. Higher cetane number leads towards improved combustion that yields lower CO, HC and PM emission [6-8]. NO_x emissions can also be reduced by increasing the EGR ratio without significant smoke penalty up to a certain level [3, 9]. GTL fuel and its blend with diesel and Biodiesels may not only significantly upgrade the fuel properties of these blends but also can achieve low emissions without any major engine modifications and insignificant loss in efficiency [6, 10, 11]. In Malaysia, diesel is now mixed with 5% biodiesel known as B5 diesel. GTL diesel blending with B5 diesel can achieve further improvements in respect of engine performance and emission.

2. Experimental Set up and procedures

2.1. Fuel blend preparation and property analysis

B5 Diesel was mixed with GTL diesel fuel to improve the fuel properties and also the engine performance and emission characteristics. These two fuels were mixed to obtain blends containing 20% and 50% GTL by volume in B5 diesel and are designated as D80G20 and D50G50, and GTL100 is 100% GTL. Calculated volumes of B5 diesel and GTL was taken into a sealed mixing facility, positioned first in a magnetic stirrer and next in a shaker. Blend sample was removed and observed for 12hrs to ensure that no phase separation was occurred.

The blended fuels showed improved fuel property with the presence of GTL in blend definitely in terms of kinematic viscosity and density. The apparatus for fuel property analysis and experimental values are depicted in Table 1 and Table 2 respectively.

Table 1. Equipment for fuel property testing

Properties	Equipment
Density	Stabinger Viscometer SVM 3000
Kinematic Viscosity	Manufacturer: Anton Paar
Flash point	Pensky-Martens flashpoint automatic NPM 440
	Manufacturer: Normalab, France
Calorific Value	Semi auto bomb calorimeter
	Model: 6100EF
	Manufacturer: Parr, USA

Table 2: Characteristics of the investigated fuels

Properties	Diesel B5	GTL	D80G20	D50G50
Density @ 40°C (gm/cc)	0.8328	0.7619	0.8178	0.7922
Kinematic viscosity @ 40°C (mm ² /sec)	3.4626	2.7417	3.2761	3.1253
Flash Point (°C)	77.5	103.5	83.5	88.5
Calorific Value (MJ/Kg)	44.664	46.805	45.026	45.734
Cetane NO.	55	75	70	65

2.2. Engine Test

YANMAR TF 120-M diesel engine was used for experimental investigation. The test rig schematic and engine specification are depicted in Fig. 1 and Table 3 respectively. Initial engine run was performed with Diesel before starting the tests with B5 diesel, GTL, D80G20 and D50G50 fuels. Engine testing conditions performed at full load and within speed range of 1200~2400 rpm at an interval of 200rpm. Performance test was governed by Dynomax-

2000 software in a laptop interfacing to the engine test bed (Fig. 1). BOSCH Exhaust gas analyzer BEA-350 was used to investigate exhaust emissions of fuels.

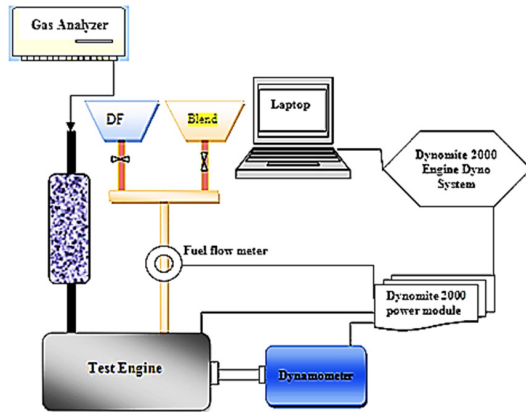


Fig. 1. Schematic of experimental set up

Table 3: Engine Specification

Engine type	4 Stroke DI diesel engine
Number of cylinders	One
Aspiration	Natural aspiration
Cylinder bore * stroke (mm)	92*96
Displacement (L)	0.638
Compression ratio	17.7
Maximum engine speed (rpm)	2400
Maximum power (kW)	7.7
Injection timing (deg.)	17° bTDC
Injection pressure (kg/cm ²)	200
Power take off position	Flywheel side
Cooling system	Radiator cooling

3. Results and discussion

3.1. Engine Test performance

3.1.1. Engine power output

Fig. 2 compares the power output of the test engine fuelled with B5, GTL and their blends. Though the engine was unmodified GTL and its blends showed slightly improved power output than B5 Diesel. At 1800 rpm, highest power achieved by all fuels where GTL demonstrated about 10.1% higher power than B5 diesel. The higher calorific value of GTL and improvement of density and viscosity in the blends improved the atomization process during combustion, that yields improved combustion and also reflected the slight improvement in power output [11, 12].

3.1.2. Brake specific fuel consumption

Fig. 3. Illustrates the brake –specific fuel consumption (BSFC) of GTL-diesel blends versus engine speed. It was observed that both blends improved the BSFC compared to B5 diesel. Lowest BSFC showed by all fuels at 1800 rpm. GTL showed about 9.29% lower BSFC than B5 Diesel. Improvement of BSFC in GTL and GTL-B5 diesel blends than diesel due to higher calorific value of GTL fuel [3, 12].

3.1.3. Brake thermal efficiency

Fig. 4 shows the relationship between brake thermal efficiency (BTE) and speed with GTL, B5 diesel and blended fuels. The brake thermal efficiency of all tested fuels achieved approximately 21 % at 1800 rpm. As can be observed, there is no significant difference in the BTE of all the fuels. In case of GTL operation, the brake thermal efficiency was marginally higher than other fuels [3, 11, 12].

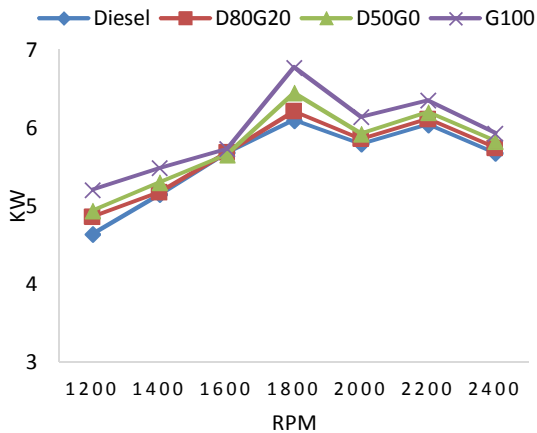


Fig. 2. Effect of engine speed on power at full load.

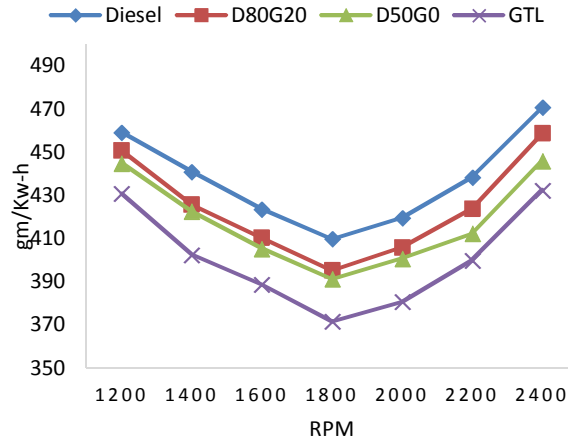


Fig. 3. Effect of engine speed on BSFC at full load.

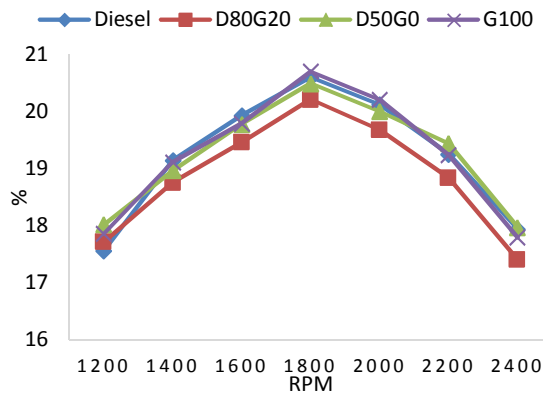


Fig. 4. Effect of engine speed on BTE at full load.

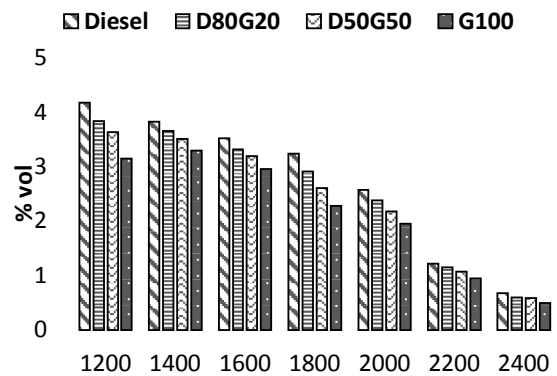


Fig. 5. Effect of engine speed on CO emission at full load.

3.2. Exhaust emission characteristics

3.2.1. CO Emission

Fig. 5 shows variations of the CO emissions for B5 diesel, GTL and their blends at various engine speed ratings. Reductions in CO levels at lower speeds for GTL and its blends relative to diesel are larger than the reductions at higher speeds. GTL showed the best reductions in CO emissions by 22~ 25% on average in all rpm compared to B5 diesel. The mysteries of CO emission reduction of GTL lie within the fuel properties and combustion phenomena of GTL. Higher H/C ratio and very low aromatic content provides improved combustion that favors CO reduction. Higher Cetane number (CN) of GTL induces shortening of ignition delay that prevents less over-lean zones. The lower distillation temperature of GTL induced rapid vaporization, which reduce the probability of flame quenching and ensures lower CO emission [11-12].

3.2.2. HC emission

Fig. 6 presents the variations of the HC emissions for B5 diesel, GTL and their blends at various engine speeds. The result demonstrates that all fuels produce low HC emissions with the increment of speed. GTL, D50G50, D80G20 shows lower emissions compared to B5 diesel. In general, GTL shows approximately 40% less HC emissions than diesel. Alike CO emission reduction HC emission reduction can be explained regarding the fuel properties and combustion phenomena of GTL. Higher CN of GTL fuel shortens the ignition delay which prevents formation of over-lean regions. Lower distillation temperature characteristic of GTL ensures proper pace of evaporation and mixing with air to constitute more effective combustible charge which results less unburned HC in exhaust emission [8, 11, 12].

3.2.3. NO Emission

Fig. 7 gives a relation of NO emission with the engine speed for B5 diesel, GTL and blends at a full engine load with variation of speed. Overall, NO emission decreases as the speed increases. Addition of GTL in blends contributes to greater NO emission reduction. D80G20 and D50G50 showed respectively about 2% and 4% decreased NO emission. In general GTL showed 6~7% reduction in NO emission compared to B5 diesel. Higher CN induced shorter ignition delay, followed by lesser premixed charge results in the lower combustion temperature and pressure. It leads towards less NO formation in the cylinder on the basis of the temperature dependent thermal NO formation mechanism [8]. Significant lower Aromatic contents of GTL fuel favors local adiabatic flame temperature which assists in NO reduction [5, 12].

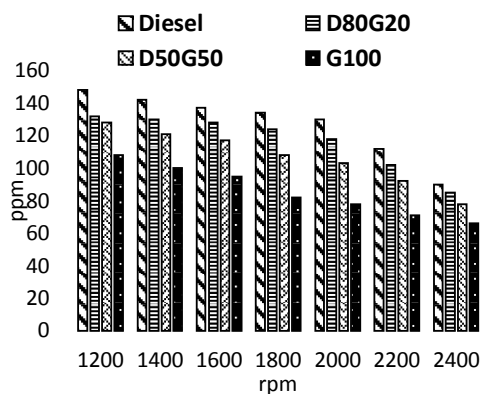


Fig. 6. Effect of engine speed on HC emission at full load.

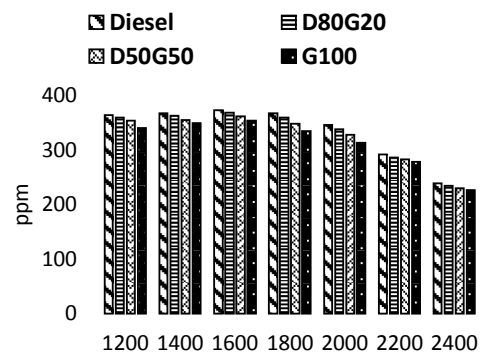


Fig.7. Effect of engine speed on NO emission at full load.

4. Conclusion

A comparative study of B5 diesel, Gas to liquid (GTL) diesel and their blends were investigated using an unmodified single cylinder test engine in terms of engine performance and exhaust emission. The outcome of the investigation can be summarized as follows:

- Since GTL has superior fuel property than B5, the blends of these two fuels showed improved fuel properties in terms of viscosity and density. GTL can be operated on unmodified diesel engines also as the performance and emission characteristics are satisfactory, even better than B5 diesel.

- Engine performance results had demonstrated improvement of GTL in all examined parameters compared to B5 diesel. GTL showed maximum increased power and brake thermal efficiency up to 10.1% and 21% compared to diesel. GTL also showed good improvement of BSFC by lowering the value approximately 9.29% compared to B5 diesel. Exhaust emission experiment had revealed overall significant reduction of CO (22~25%), HC (30~40%) and NO (6~8%) compared to B5 diesel.
- D50G50 and D80G20 both these fuel blends showed improved engine performance and exhaust emission compared to B5 diesel. D50G50 showed improved performances and emissions compared to D80G20.

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